VERBAL DISTRACTION DURING THE COMPLEX FIGURE TEST: AN ATTEMPT TO INCREASE THE SENSITIVITY TO RIGHT TEMPORAL LOBE EPILEPSY

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Abstract of Dissertation Presented to the Graduate School
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VERBAL DISTRACTION DURING THE COMPLEX FIGURE TEST: AN ATTEMPT TO INCREASE THE SENSITIVITY TO RIGHT TEMPORAL LOBE EPILEPSY

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The Complex Figure Test (CFT) is often used in neuropsychological evaluations of patients with temporal lobe epilepsy (TLE) as a measure of nonverbal memory. Although it has been assumed that individuals with TLE in the right hemisphere would have impaired memory for nonverbal stimuli, in actuality the CFT has not been shown consistently to discriminate between patients with right and left TLE. One possible explanation for the lack of significantly greater impairment after right temporal lobe damage is that those with right TLE are able to encode the figure by utilizing verbal compensatory strategies, thus reducing their reliance on visuospatial memory strategies. In the current study, the CFT was presented to 26 patients with TLE (15 right, 11 left) who were asked to perform a verbal distractor task, which was designed to prohibit verbal encoding of the figure, concurrent with the copy trial. It was hypothesized that the right TLE patients would demonstrate worse delayed

memory for the figure after the verbal distractor because they would no longer be able to rely on verbal encoding. Parallel complex figures also were presented with either a nonverbal distractor (tone sequence) task or no distractor. Results indicated that, while both right and left TLE groups had significantly worse memory for the figures presented with verbal or nonverbal distraction, there were no significant differences between groups after any of the distractor conditions. These findings suggest that right TLE patients are in fact not utilizing verbal encoding strategies to compensate for poor visual-spatial memory. Other explanations are explored. Additionally, the organizational approach to copying the complex figure was examined, with the hypothesis that patients with right-hemisphere damage would exhibit a less cohesive, more fragmented copy. Data from 29 patients with unilateral right (16) or left (13) epilepsy indicated that there were no differences between groups for copy organization.

CHAPTER 1
INTRODUCTION

Neuropsychological Assessment in Epilepsy

Complex partial epilepsy of temporal lobe origin, a syndrome in which epileptic seizures originate from a unilateral medial temporal focus, is one of the most common forms of intractable epilepsy. Surgical resection of the medial temporal structures is an increasingly viable option for treatment of seizures. Outcome results show that surgical treatment leads either to complete control over seizures or to a clinically significant reduction in seizure frequency in 70 to 90% of patients (Engel, 1987). One of the most important factors that both determines a patient's candidacy for surgery and predicts seizure outcome after surgery is the presence of a single, defined seizure focus (Benzgon, 1968; Dodrill, et al., 1986). Magnetic Resonance Imaging (MRI), electroencephalogram (EEG), and neuropsychological assessment are all important factors in determining the exact location of the seizure focus (Moser et al., 2000). The neuropsychological evaluation, which typically consists of tests designed to tap a variety of cognitive skills, has a principal goal of determining cognitive or functional deficits that may supply clues to the localization of the seizures (Jones-Gotman, 1991).

The typical neuropsychological protocol for a patient with suspected focal epilepsy generally contains subsets of tests designed to assess both verbal skills (such as verbal memory, naming, and verbal problem solving) and nonverbal skills (visuo-

evaluation, which typically consists of tests designed to tap a variety of cognitive skills, has a principal goal of determining cognitive or functional deficits that may supply clues to the localization of the seizures (Jones-Gotman, 1991).

The typical neuropsychological protocol for a patient with suspected focal epilepsy generally contains subsets of tests designed to assess both verbal skills (such as verbal memory, naming, and verbal problem solving) and nonverbal skills (visuo-constructional abilities, visual or spatial memory, and judgment of visuo-spatial relationships). Deficits in either verbal or nonverbal domains can provide clues to help determine the laterality of the seizure focus.

Material-Specificity

Through her work with temporal lobe epilepsy (TLE) patients, Milner was one of the first to hypothesize that medial temporal lobe structures were involved in material specific memory processes. She published a large-scale study comparing the nonverbal memory abilities of patients who had cortical resections (of either the right or left temporal lobe, parietal lobe, or frontal lobe) to a group of normal controls (Milner, 1968). Each patient was asked to study an array of unfamiliar target faces for a short time, and later asked to pick out the target faces from a larger array of faces. Results indicated that patients with right temporal lobe resections were worse than any other group at recognizing faces after a delay. She also found that patients with right temporal lobe resections who had large hippocampal resections performed significantly worse than did those with relatively spared hippocampi. In fact, patients

with right temporal resections but a spared hippocampus did not perform significantly worse than did the patients with left temporal lobe resections.

Considering this pattern of results, Milner concluded that one very important structure for delayed nonverbal memory was the right hippocampus. She hypothesized that the right hippocampus is involved in consolidation of nonverbal material, either by active rehearsal or by another, more automatic, process. She believed that impairments in nonverbal consolidation led to impaired delayed memory performance for patients with right TLE (Milner, 1968).

Since Milner first proposed her views on material-specificity, research in the area of lateralized memory responsibilities has continued. Kimura (1963), while attempting to demonstrate that right temporal lobe damage caused visual disturbances, discovered that patients with right-lateralized temporal lobe foci were able to discriminate among nonverbal stimuli, but demonstrated nonverbal memory deficits. Specifically, the right TLE group had difficulty making judgments of unfamiliar nonverbal material (i.e., recognition of abstract figures, counting random dots) presented tachistoscopically. Their performance on the same test using familiar stimuli (e.g., letters, familiar objects) was normal. In addition, she found that the right TLE group was worse at recognizing unfamiliar geometric and abstract designs.

Long-term recall for the Rey-Osterrieth Complex Figure (ROCF; Osterrieth, 1944; Rey, 1968), a complicated design that an individual first copies and later draws from memory, is used commonly in contemporary neuropsychological evaluations to assess memory for visuo-spatial material. Taylor (1969) found that right TLE patients performed worse on delayed (one-hour) memory for the figure than did left

TLE patients, even though there were no group differences for copying ability. Taylor reported that, postsurgically, the recall scores of his patient groups became even more discrepant. He found that left TLEs performed better on the ROCF delayed recall trial after surgery and that right TLEs performed worse compared to their own pre-surgical performance.

Fedio and Mirsky (1969) reported material-specific deficits in a sample of children with right and left TLE. They compared the performance of children with unilateral TLE with children whose epilepsy did not show a specific, lateralized seizure focus. They found that children with left TLE, in contrast to the other groups, achieved lower scores in the Verbal domain of the Wechsler Intelligence Scale for Children, while children with right TLE had lower scores in the Performance domain. Additionally, the right TLE group was impaired on supraspan tests involving nonverbal stimuli. Finally, the children with right TLE had an impaired ability to remember the ROCF after a short (three-minute) delay.

Delaney and colleagues studied TLE patients with medically controlled seizures and found that right TLEs, as compared to left TLEs and patients with frontal lobe epilepsy, were not impaired on immediate recall of the Wechsler Memory Scale (WMS) Visual Reproduction figures but remembered significantly less figural detail after a 30-minute delay. In addition, the right TLE patients demonstrated worse overall performance on the Recurring Figures Test. These results demonstrated material-specific deficits in patients who did not have large surgical resections or who had a long history of poorly controlled seizures (Delaney, Rosen, Mattson, and Novelly, 1980).

Although some evidence supports the material-specificity theory, many studies have not replicated the work of Milner and others. For example, after comparing a right TLE group with a left TLE group pre- and post-surgically, Lee, Loring, and Thompson (1989) found no significant differences either for delayed recall of a complex figure or for recognition of a series of geometric shapes. Furthermore, they found that, contrary to their expectations, the right TLE patient group's performance did not significantly worsen after anterior temporal lobectomy (ATL). The authors argued that the nonverbal memory tests may not have been sensitive to right hippocampal damage or removal because the stimuli could have been simple enough and familiar enough to be verbalized during encoding.

Barr and his colleagues conducted research on two of the most commonly used nonverbal memory tests for contemporary neuropsychological evaluations of epilepsy: the ROCF and the Wechsler Memory Scales (WMS or WMS-R) Visual Reproduction (VR) subtest. They combined data from several well-established epilepsy research and treatment centers around the United States and Canada. Based on the performance of over 700 patients, they concluded that neither the VR nor the ROCF immediate recall scores, delayed recall scores, or percent-retained scores were able to reliably discriminate between right and left pre-surgical TLE patients. In their article, the researchers argued that current research must be directed toward finding more sensitive measures of nonverbal memory. Specifically, they stated that the construct of nonverbal memory itself needed to be thoroughly re-examined (Barr et al., 1997).

Two studies examined presurgical performance on the Continuous Visual Memory Test (CVMT), which was modeled after Kimura's Recurring Figures Test (Parsons, Kortenkamp, Bauer, Roper, and Gilmore, 1997; Snitz, Roman, and Beniak,1996). However, neither group found impaired performance on the CVMT to be predictive of right TLE.

Brain-imaging studies have also obtained mixed results regarding material-specificity. Using MRI data, Lencz et al. calculated hippocampal and temporal lobe volumes from patients with intractable temporal lobe epilepsy. When they attempted to relate the size of the hippocampus and temporal lobe with neuropsychological data, they found that, in a left TLE patient group, there were indeed significant correlations between the left temporal lobe and hippocampal volumes and percent retention on a verbal memory measure. A significant relationship also existed between left temporal lobe volumes and performance on a verbal selective reminding test in the left TLE patients. However, there were no significant correlations among any of the tests, including a visual memory test, and right hippocampal or right temporal lobe volumes (Lencz et al., 1992).

Evidence from studies of hippocampal cell counts, obtained by examining resected hippocampal tissue, have typically found a relationship between the left hippocampus and verbal memory but have not been able to conclude that a similar relationship existed between the right hippocampus and nonverbal memory abilities. For example, one study found that poor verbal memory correlated with cell loss in specific subfields of the hippocampus in patients with left temporal lobe epilepsy (Sass et al., 1992). Other researchers (Rausch and Babb, 1993) found that poor

performance on a verbal paired associate learning test was correlated with damage in a region of the left hippocampus. However, neither of these studies reported specific relationships between the degree of pathology in the right hippocampus and nonverbal memory impairment. Additionally, while Kortenkamp et al. (1996) found significant correlations between neuronal dropout in the left hippocampus and verbal memory deficits, no significant correlations were found between right hippocampal sclerosis and nonverbal memory performances.

Taken together, these results suggest that, although left TLE is consistently associated with verbal memory deficits, the precise effect of right TLE on nonverbal memory performance has not been determined conclusively. Some of the inconsistencies in the literature are likely due to different criteria in patient selection. For example, Milner's original research on material specificity was done on post-surgical patients. A post-surgical patient group would be expected to have more severe deficits than would a pre-surgical population because of the removal of key temporal lobe structures, such as the hippocampus and surrounding cortex, which might be partially functional in pre-surgical patients. Additionally, due to improved surgical procedures and better-resolution brain-imaging techniques, the amount of tissue resected during surgery for epilepsy conceivably could be much less, or at least could be more clearly defined, than it was 40 years ago, when some of the early data supporting the material-specificity hypothesis was collected on post-surgical patients. In fact, the resection sizes reported by Milner (1968) ranged from 4 to 7.5 centimeters. More recently, other papers reported the standard "en bloc" hippocampal

resections to be between 5.5 and 6.5 centimeters (Nunn, Graydon, Polkey, and Morris, 1999).

Another factor likely to account for some of the inconsistency in the literature is the method used to assess nonverbal memory. Some such methods involve motor skills, such as drawing or tapping, which may confound results depending on the motor dominance of the patients, while others involve more pure spatial skills or visual recognition skills, which do not rely on motor output. Other factors, such as the presence or absence of hippocampal sclerosis and seizure variables (seizure frequency, age of onset, etc.) likely play a role in the variability of patients' performance. However, the fact that many earlier findings have not been replicated even when careful consideration was given to the above-mentioned factors calls into question the utility of traditional nonverbal memory assessment techniques in localizing seizure focus.

One possible explanation for the inability of nonverbal memory measures to discriminate consistently between right and left temporal lobe epilepsy patients is that perhaps traditional nonverbal memory tests inherently contain a significant confound, verbalizability. Several researchers have considered that stimuli in traditional nonverbal memory tests may be too easily encoded verbally. If such is the case, it could take the responsibility off of the nondominant hemisphere to encode the material visuo-spatially (Barr et al., 1997; Lee et al., 1989).

Evidence that "nonverbal" stimuli are verbally encoded by patients with right TLE is presented by Helmsteader and colleagues (Helmsteader, Pohl, and Elger, 1995). The researchers pointed out that prior studies of memory performance using

the Benton Visual Recognition Test (BVRT), which contains an array of geometric designs, provided no evidence that performance on the test discriminates between right and left TLE patients. The researchers created a revised scoring system for the test that took into account the verbal content of each stimulus by assigning points based on form, size, position, and other verbalizable characteristics of each figure. After analyzing performance in light of what they termed the "verbal load factor", they found that right TLE patients had a significantly greater loss of verbal information than did the left TLE patients, especially on very complex items. More important, the revised scores directly correlated with immediate recall performance on an auditory verbal list learning test for the right TLE patients only, indicating the possible involvement of verbal strategies in this group. Finally, analyses determined that BVRT scores were correlated with verbal retention scores for the right TLE group only for very complex items (i.e., greater than 8 verbalizations). The authors concluded from their findings that patients with right TLE recruited left hemisphere regions to apply verbal strategies to encode complex visual information, thus allowing them to overcome visual memory deficits and to perform as well as left TLE patients perform.

Further evidence for the verbalization of "nonverbal" stimuli includes results from studies of tests without easily verbalized stimuli, such as more spatially oriented tests (Abrahams, Pickering, Polkey, and Morris, 1997; Feigenbaum, Polkey, & Morris, 1996). Initial results suggest that spatial memory tests may be better able discriminate between the groups with left versus right TLE. Spatial material may be

less easily verbalized than visually presented material, which typically contains namable features.

Because material eventually encoded into long-term store is thought to first be processed in the working memory system (Baddeley, 1996), working memory was considered a major component in the current study. In the next section, the different components of working memory will be reviewed.

The Role of Working Memory in Encoding

Baddeley and Hitch (1974) presented a fractionated theory about working memory. They hypothesized that the construct of working memory consists of three general components: a phonological loop, which is responsible for storing and manipulating verbal information, a visuo-spatial sketchpad, which is needed to store information about a stimuli's visual and spatial properties, and a central executive processor important for controlling attention to the other two systems. Baddeley (1996) further explained that working memory appears to have two main roles. The first is for the manipulation and retrieval of new information. The second role of working memory is to register newly acquired information into the long-term store.

According to the fractionated theory of working memory, the articulatory loop and the visual-spatial sketchpad process different information. Furthermore, it has been shown that the visuo-spatial sketchpad is actually composed of independent visual and spatial processing components. Brain-mapping studies of primates and humans have shown different patterns of activation for working memory tasks involving spatial information (i.e., object location) or object-based information (i.e.,

pattern analysis) in several brain regions including frontal and occipital cortex (Courtney, Ungerleider, Keil, & Haxby, 1996; Wilson, Scalaidhe, and Goldman-Rakic, 1993). Additionally, studies investigating behavioral tasks have shown that visual and spatial information can be processed simultaneously without one disrupting the other. However, two tasks involving the same subsystem of the visuospatial sketchpad (e.g., two spatial tasks) caused impaired performance. The researchers concluded that the concurrent tasks within a subsystem caused a resource conflict due to the tasks involving a common neurocircuitry (Smith et al, 1995; Tresch, Sinnamon, and Seamon, 1993).

Neuroimaging studies have shown distinct laterality patterns for verbal and nonverbal working memory tasks. Smith and Jonides (1997) used positron emission topography (PET) during working memory tasks involving spatial, object, and verbal information. They found that spatial tasks activated more right hemisphere brain regions whereas left regions were more active during verbal working memory conditions.

Baddeley and Hitch's theory implies that verbal encoding in working memory can be prohibited if the phonological store is somehow prevented from actively processing information. This disruption of verbal processing would force the visuo-spatial sketchpad, and thus the non—language-dominant hemisphere, to be solely responsible for encoding information for storage in long-term memory. Several techniques of preventing the phonological loop from processing and encoding information have been described in the literature. In an article reviewing his working memory theory, Baddeley (1992) described how both irrelevant speech (background

spoken language) and articulatory suppression (the repetition by the subject of irrelevant speech sounds) can each disrupt the phonological loop.

Evidence that articulatory suppression and irrelevant speech can disrupting verbal encoding of visually presented information is plentiful. For example, when words are presented visually, memory for a word list containing phonologically similar items is worse than memory for a list of less similar words (Conrad and Hull, 1964). This is often referred to as the phonological similarity effect. Interestingly, when articulatory suppression is utilized during list presentation, the phonological similarity effect disappears. Baddeley (1997) attributed this to the fact that the words are not subvocally articulated, and thus confusion among the words based on how they sound is prevented.

Articulatory suppression also eliminates the word length effect, the tendency for lists of short words to be remembered better than a list containing the same number of longer words, when the stimuli are visually presented. It is thought that this effect is due to the fact that short words can be rehearsed more quickly and thus more frequently. In fact, the word length effect appears to be more a function of the amount of time a word needs for articulation than its absolute length or number of syllables. For example, word lists containing long two-syllable words such as voodoo and humane are less well remembered under normal conditions than are short two-syllable words like bishop and wicket (Baddeley, Thompson, and Buchanan, 1975). Baddeley (1997) theorized that articulatory suppression prevents subvocal verbal rehearsal, thus eliminating the word length effect.

Postma and DeHaan (1996) experimented with articulatory suppression during working memory in order to determine the degree to which it affected memory for different types of visually presented stimuli. During trials requiring the articulatory suppression paradigm (counting backwards from 100), as compared to trials without articulatory suppression, their subjects had more difficulty remembering locations of specific letters and objects. However, articulatory suppression had very little effect on memory for spatial location only. These results indicated that verbal encoding of easily labeled stimuli was disrupted by the articulatory suppression paradigm, while information that is difficult to verbalize (i.e., spatial locations) was virtually unaffected.

The irrelevant speech effect also has been shown to disrupt the phonological loop. Subjects who attempt serial immediate recall perform worse if there is random speech, even if in a language they do not understand or nonsense syllables, in the background. However, the same is not true if the background noise is not speech but simply white noise, patterned noise, or instrumental music (Salame and Baddeley, 1987).

In essence, studies using both articulatory suppression and irrelevant speech paradigms have determined that both techniques actually do prevent a subject from translating visual information into verbal codes. When verbal coding is prohibited, memory must depend entirely on nonverbal encoding, rehearsal, and retrieval processes.

Purpose of the Present Study

The purpose of the current study was to investigate the possibility that verbal encoding during stimulus presentation in patients with right TLE allows them to perform as well as left TLE patients on memory tests that are traditionally thought of as nonverbal. Complex visual material was presented to right and left TLE patients concurrent with a distracting verbal task and the effects of memory for the visual material was investigated. In order to conclude that any differences in performance were due to the verbal nature of the task, rather than to the attentional demands of a concurrent task, another complex visual figure was presented concurrent with a nonverbal distracting task. The goal was for the output demands of the verbal and nonverbal distracting tasks to be as similar as possible. Because it was not possible to find a nonverbal correlate to an articulatory suppression technique, irrelevant background speech was used as the distracting verbal task. Background tone sequences were used as the nonverbal distracting task.

CHAPTER 2

HYPOTHESES

It was hypothesized that normal subjects would show worse memory for the complex figures after verbal and nonverbal distraction, due to the extra processing resources required to attend to the distraction tasks. However, the performance of normal pilot subjects was not expected to be worse after verbal distraction when compared to nonverbal distraction, because neither distraction task was expected to interfere with visuospatial encoding.

It was hypothesized that right TLE patients utilize verbal compensatory mechanisms to improve their memory for nonverbal material. Therefore, it is postulated that by presenting distracting verbal material during the encoding phase of a complex figure task, the right TLE patients' memory for the figure will be worse after a delay than the left TLE group's memory. It was also hypothesized that verbal distraction would have a minimal effect on the left TLE group's delayed memory performance because verbal encoding is likely to be already impaired in this group. Therefore, they are likely to rely on visuospatial encoding, which should not be disrupted by the verbal distractor task.

There were no hypothesized group differences for recall of the figures during the nonverbal distractor condition. Because the nonverbal, tone-monitoring task is not assumed to disrupt either verbal or visuospatial encoding, both the left and right TLE groups should be able to encode and retrieve the figure as they normally do. If there are no group differences in figure memory after the distractor task, this will

indicate that the right and left TLE groups do not differ in their ability to divide their attentional and processing resources between two concurrent tasks.

Finally, it was hypothesized that patients with right hemisphere epilepsy would demonstrate worse organization of the complex figures during encoding when compared to left hemisphere patients, reflective of the right TLEs impaired visuospatial skills. Support for this hypothesis would replicate past studies that found poorer copy organization after right hemisphere damage compared to left hemisphere damage (Gianotti and Tiacci, 1970; Lange, Waked, Kirsblum, and DeLuca, 2000). Because neither verbal nor nonverbal distraction is assumed to affect visuospatial processing, neither distraction task should further impair organization of the figures.

CHAPTER 3

METHODS

Participants

Eleven normal control subjects were recruited for a pilot study of the modified (described below) complex figure tests. They were recruited from the University of Florida's undergraduate Introductory Psychology pool.

Data were collected from 35 patients with unilateral temporal lobe epilepsy. A total of 26 of these patients were included in this study because they demonstrated a unilateral temporal lobe epileptic focus based on decisions made by a multidisciplinary epilepsy management team that used results of EEG monitoring, brain imaging, and neuropsychological data. Fifteen of the patients had a determined right temporal lobe focus and 11 had a left temporal lobe seizure focus. In addition, three subjects with non-temporal but unilateral seizure foci were included in some of the analyses. One had a right frontal lobe focus and two had diffuse left hemisphere epileptogenic discharges. Of the total group of 29 patients, nine were postsurgical patients who had previously undergone unilateral anterior temporal lobectomy (7 right ATL, 2 left ATL). The postsurgical patients all met criteria for Class I or Class II postoperative ratings as described by Engel et al. (Engel, Van Ness, Rasmussen, and Ojemann, 1993) at three or six month follow-up. These classifications require that the patients

are either seizure-free (excluding early postoperative seizures) or have only rare seizures. Nineteen members of the total patient group were patients being treated at a major teaching hospital in Florida and 10 were patients at a major medical center in New York. In order to participate in this study the patients had to meet the following criteria: no history of major head trauma, no current DSM-IV diagnosis of drug or alcohol abuse or dependence, and no current psychotic symptomatology at the time of evaluation. Additionally, all subjects had a WAIS Full Scale IQ score or NART predicted IQ score of greater than 70, and were between the ages of 18 and 64. All patients had typical language dominance as determined by the Wada procedure (Wada and Rasmussen, 1960; Willmore et al., 1978). All pilot subjects and patients gave informed consent for involvement in this study. Human subjects approval was granted by the Institutional Review Board at the University of Florida Health Science Center (IRB-01) and by the Office of Grants and Contracts of the North Shore - Long Island Jewish Health Care System.

Materials

Each pilot subject and patient was assessed using two modified presentations of the Complex Figure Test. The use of a novel complex figure was deemed essential due to the fact that many subjects involved in this study had previously been exposed to the ROCF during clinical assessments. The figures used were developed by researchers at the Medical College of Georgia (MCG) for use as parallel forms of the ROCF (MCGG Complex Figures; Loring and Meador, in press). Loring and Meador showed that the figures included in this study (Figures 1, 2, and 4) are of virtually equal difficulty to remember. Furthermore, even though studies have shown that

these figures may be slightly easier for subjects to recall than the ROCF, they are similar in that they are complex abstract figures. The visuospatial aspects of the figures were designed to be very similar to the ROCF. And, similar to the ROCF in many studies, the MCG figures have not been consistently shown to discriminate between right and left TLE patients post-surgically (Lee et al., 1989; Loring and Meador, in press).

The modified presentations of the Complex Figure Test were presented within a traditional neuropsychological evaluation, which included several other tests of cognitive functioning. Each subject was given a verbal list learning test, either the Hopkins Verbal Learning Test – Revised (HVLT-R; Benedict, Schretlen, Groninger, and Brandt, 1998) or the California Verbal List Learning Test (CVLT; Delis, Kramer, Kaplan, and Ober, 1987), which consists of 12 to 16 words that are presented across 3 to 5 learning trials. After each presentation, the subject was asked to recall as many words as possible from the list. The subject was again asked to recall as much of the word list as possible after a 15 to 35 minute delay interval. Percent verbal retention scores were calculated for each subject by dividing the number of words recalled after the final learning trial by the number of words recalled after the delay period. Each subject also completed a verbally presented information questionnaire inquiring about relevant seizure history, past head injuries, hand dominance, and psychiatric history.

Every pilot subject, as well as every epilepsy patient who did not have intelligence data from a recent neuropsychological evaluation, was administered a National Adult Reading Test (NART; Nelson, 1982) to estimate IQ scores. NART

formulated IQ estimates have been shown to correlate between .72 to .81 with actual IQ scores (Lezak, 1995).

Procedures

Each subject was tested using two modifications of the Complex Figure Test (CFT); verbal distraction and nonverbal distraction (described below). Additionally, all pilot subjects and any members of the patient group who had not undergone a recent neuropsychological evaluation also were tested using the standard presentation of the complex figure. The figures used for each of the conditions and the order of the conditions were counterbalanced for pilot subjects and were randomized for patients.

Verbal Distraction

An audiotape with one-syllable words was used as a verbal distractor. Subjects were told simply to say "yes" each time they heard an animal name mentioned on the tape. Each subject was allowed to listen to the first nine words (including 2 targets) as practice as many times as necessary until they obviously understood the task. One MCG complex figure was presented before each subject on a sheet of 8.5"x11" paper. They were then asked to copy the figure on a blank page as accurately as possible and to take as much time as they needed. They were warned that they would be asked to remember the figure later. In addition, the importance of performing as well as possible on the distractor task was stressed.

Nonverbal Distraction

Presentation during the nonverbal distractor condition was identical to the presentation described above except that a tone-monitoring task was used as a form of

nonverbal distraction. For this task, subjects listened to a series of tones and were asked to respond "yes" when they heard two high tones presented in a row. This procedure is identical to that described in more detail by Binder and colleagues (Binder et al., 1995) except that is was slowed down slightly to make it less difficult.

No Distraction

During this phase of the experiment, the complex figure was presented in the standard manner. That is, the subject simply was asked to copy the figure onto a blank page of paper as accurately as possible, taking as much time as needed. Subjects were told that they would be asked to recall the figure later.

Fifteen minutes after the initial figure presentation, subjects were asked to draw as much of the figure as they could remember (delayed recall trial). Each copy and delayed recall trial figure was scored using the Medical College of Georgia scoring criteria (Loring and Meador, in press), an 18-point scoring system based on Lezak's modification of Rey's scoring system for the ROCF (Lezak, 1995).

During all copy and delayed recall trials, the examiner made a flowchart of the subjects' drawings and kept track of the order in which each copied or recalled component was drawn. This flowchart was used to determine the extent to which each subject used efficient organization strategies (perceptual organization score). Evaluation of organization was based on Shorr, Delis, and Massman's (1992) ROCF perceptual cluster score. The juncture points of each of the three MCG scores were determined and subjects were given one point for drawing lines contiguously across the junctures. There were 18 junctures scored for each of the three figures. However, because the four junctures of the large rectangle or square had to contain at least one

break (where the first and last sides drawn meet) the maximum perceptual organization score was 17. The number of continuous junctures was divided by 18, or the highest possible score if a drawing contained omissions, to obtain a percentage score.

CHAPTER 4

RESULTS

Pilot Subjects

An alpha level of .05 was used for all statistical tests. Descriptive data regarding the pilot subjects are shown in Table 1.

Behavioral Data.

Paired t-tests were used to determine whether error rates differed between the two distractor tasks. The pilot subjects made a significantly higher percentage of errors during the nonverbal distraction task ($M = 10.27$, $SD = 9.11$) when compared to the verbal distraction task ($M = 4.23$, $SD = 3.14$; $t = 2.35$, $p = .04$).

Because three complex figures were presented to the pilot subjects during a one-hour testing session, interference effects needed to be examined. For each pilot subject, the second and third figures were scored as to how much interference they contained from previous figures. Only three of the 11 pilot subjects demonstrated interference on delayed recall of their second and third figures. Additionally, each of the three mistakenly remembered only one feature each. Therefore, it was determined that interference across memory trials for the complex figures was not a significant concern.

Percent Retention Scores

Percent retention scores were analyzed using a repeated measures analysis of variance (ANOVA). The dependent variable was percent delayed retention after each copy condition (no distractor, verbal distractor, nonverbal distractor). The ANOVA obtained significant differences in percent retention among the three copy conditions [F (2, 20) = 18.72; p = .000). Paired t-tests comparing the percent delayed retention after each condition further indicated that memory performance was worse after both verbal and nonverbal distraction when compared to the no distractor condition. The average percent delayed retention for the figure presented during the no distractor condition was 76.31, whereas the average percent delayed retention after the verbal distraction was 43.15 (t = 5.54, p = .000). Average delayed percent retention after the nonverbal distractor condition was 50.57 (t = 4.06; p = .002). The difference between delayed retention after the verbal distractor vs. the nonverbal distractor was not significant (t = 1.62, p = .137). For performance descriptives of the pilot group, refer to Table 1.

Table 1.

Mean Percent Retention Scores

		Condition		
Group	n	No Distractor	Verbal Distractor	Nonverbal Distractor
Pilot Subjects	11			
M		76.31	43.15	50.57
SD		13.18	14.58	11.37

Relationship between Verbal Retention and Visual Retention

Percent delayed retention was calculated for a verbal list learning task (HVLT-R) for each pilot subject and termed a "verbal retention score." A Pearson's Product Moment bivariate correlation indicated that verbal retention was significantly correlated with percent delayed retention of the complex figure when it was copied under the "no distractor" condition ($r = .66$; $p = .037$). However, verbal retention was not significantly correlated with percent retention during either the verbal ($r = .118$, $p = .730$) or nonverbal ($r = -.263$, $p = .435$) distractor conditions. Figure 1 shows the obtained relationships. Analysis of Fischer's r to z statistics determined that only the correlations achieved between verbal retention and figure retention under the no distraction condition vs. the nonverbal distraction condition were significantly different ($p = .003$) from each other.

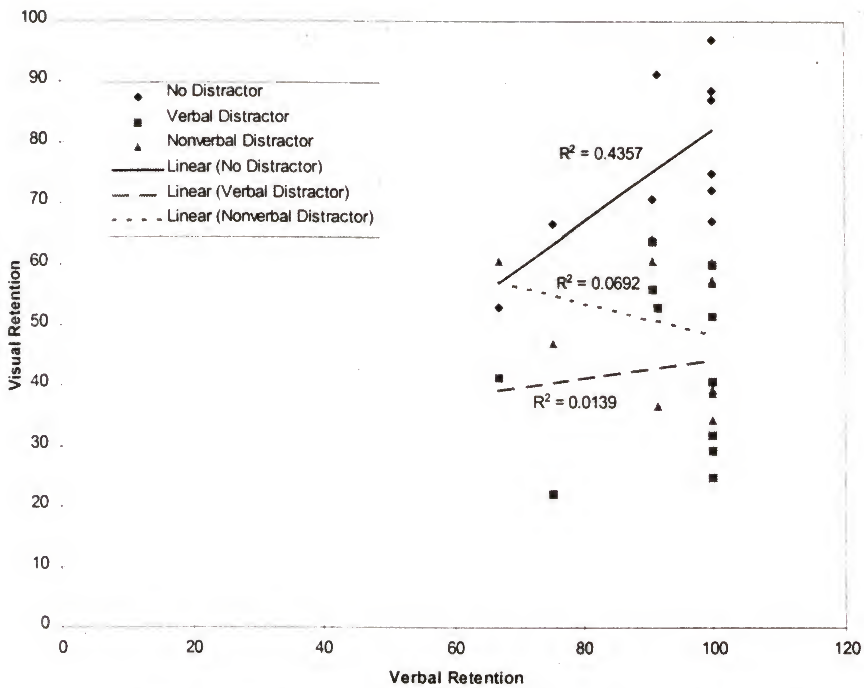

Figure 1. Pilot subject correlations between verbal retention and visual retention under the three conditions (n = 11).

Perceptual Organization

A one-way repeated measures ANOVA compared perceptual organization (PO) scores during the copy trials of the three copy conditions to see if copy condition affected organization of the figure copy. The ANOVA was not significant [$F(2, 20) = .877$; $p = .432$]. Average perceptual organization scores across the various conditions are reported in Table 2.

Table 2.

Perceptual Organization Scores on the Copy Trails - Pilot Subjects

Condition	Score
No Distraction	
M	91.41
SD	5.19
Verbal Distraction	
M	85.35
SD	14.54
Nonverbal Distraction	
M	86.87
SD	12.24

Memory for Features

Gianotti and Tiacci (1970) found that patients with left hemisphere damage simplified designs at recall, omitting some of the features. Therefore, it was speculated a posteriori that perhaps occupying left hemisphere processing through verbal distraction would cause subjects to perform similarly to individuals left with hemisphere damage, resulting in more simplified design recall. Each figure had ten salient, nameable features (e.g., cross, triangle, arrow). A feature score was created for each subject to determine how many of the original features were recalled after the delay period. Paired-samples t-tests indicated that, within the normal pilot subject group, the average number of features recalled after the no distractor condition (M = 7.45, SD = 1.8) was significantly higher than the number of features recalled after the verbal distractor (M = 3.36, SD = 1.8; t = 4.77, p = .001) and the number of features

recalled after the nonverbal distractor (M = 5.18, SD = 1.3, t = 2.98, p = .014). In addition, consistent with the hypothesis, there were more features recalled after the nonverbal distractor than were recalled after the verbal distractor (t = 2.96, p = .014).

Epilepsy Patients

An alpha level of .05 was used for all statistical analyses. Unless otherwise noted, analyses were conducted on data from only the 26 patients with confirmed TLE. Demographic information regarding the patient group can be found in Table 3. There were no significant differences between the right TLE and left TLE groups' age; education levels; or verbal, performance, or full scale intelligence scores. In addition, when looking at data from all 29 epilepsy patients, there were no significant differences on any of the demographic variables between the patients recruited in Florida and the patients recruited in New York.

Table 3.

Descriptive Statistics

Group	n	Age	Education	FSIQ
		Demographic Variable		
Right TLE	15			
M		45.21	13.36	97.77
SD		7.78	1.74	14.20
Right Epilepsy	16			
M		43.60	13.40	97.77
SD		9.67	1.68	14.20
Left TLE	11			
M		38.82	14.27	100.00
SD		11.00	2.83	13.72
Left Epilepsy	13			
M		37.77	14.00	98.30
SD		10.49	2.68	13.72
Florida Patients	19			
M		40.83	13.22	102.00
SD		9.72	1.99	13.63
New York Patients	10			
M		41.00	14.50	91.78
SD		11.94	2.37	12.7

Behavioral Data

In order to determine whether the patient groups made significantly more errors on one of the distractor tasks, a 2 x 2 (side of focus x distractor condition) ANOVA was conducted for all 29 epilepsy patients. The percent error score was the dependent variable. There was no side by condition interaction [$F(1,20) = .06$, $p =$

.813]. However, there was a main effect of condition [$F(1, 20) = 5.19$, $p = .034$]. Means collapsed over group indicated there were significantly more errors made during the nonverbal task ($M = 16.09$, $SD = 16.63$) when compared to the verbal task ($M = 7.45$, $SD = 7.57$).

As with the pilot group, there was a concern that presenting multiple complex figures consecutively might result in recall interference. Therefore, responses at delayed recall were scored to determine if they contained any features mistakenly recalled from previous figures. Seven of the patients had interference scores of two points or less. Two points of interference is consistent with one feature remembered incorrectly. While that was a slightly higher rate of interference than seen for the pilot subjects, it was still minimal and deemed acceptable.

Percent Retention Scores

Mean percent retention scores for patient groups under each condition are presented in Table 4.

Presurgical Patients. A 2 x 3 (side x condition) repeated measures ANOVA comparing presurgical patients with right or left temporal lobe epilepsy in regards to figure retention was conducted. There were no significant interactions between side of seizure focus and task condition [$F\ (2, 30) = .330$, $p = .721$]. However, a significant main effect of condition was found [$F(2, 30) = 12.469$, $p = .000$]. After collapsing the presurgical retention score data across side of seizure focus, it was found that percent retention scores were better when no distractor was present during the figure copy as

compared to retention after the verbal distractor ($t = 3.68$, $p = .002$) or retention after the nonverbal distractor ($t = 4.56$, $p = .000$).

Pre- and Postsurgical Patients. Because there were no significant differences between the presurgical patient groups on the retention variables, postsurgical patients were added to the analysis to increase power . A 2 x 3 (side x condition) repeated measures ANOVA was conducted. No side by condition interactions were detected [F (2, 48) = .251, $p = .779$]. However, there was again a significant main effect of condition [F(2, 48) = 23.14, $p = .000$]. After collapsing the TLE patient data across side of seizure focus, it was found that, consistent with performance of the presurgical patients, percent retention scores were better when no distractor was present during the copy trial then when either the verbal distractor ($t = 5.66$, $p = .000$) or the nonverbal distractor ($t = 6.24$, $p = .000$) was present.

Post-hoc analyses were conducted to determine if it would be possible to discriminate between right and left TLE patients based on rank-ordered percent retention scores. Mann-Whitney tests concluded that right and left patient groups were not distinguishable from each other based on ranked percent retention scores after nonverbal ($Z = .935$, $p = .350$) or verbal ($Z = .234$, $p = .815$) distraction.

Table 4.

Mean Percent Retention Scores - Patient Groups

Group	n	No Distractor	Verbal Distractor	Nonverbal Distractor
		Condition		
Right TLE (presurgical)	8			
M		49.31	37.29	32.04
SD		17.46	12.11	9.83
Right TLE (postsurgical)	7			
M		60.04	32.33	34.54
SD		17.28	11.42	22.79
Right TLE (Total)	15			
M		54.32	35.44	33.21
SD		17.64	11.55	16.51
Left TLE (presurgical)	9			
M		55.84	37.27	34.25
SD		9.29	19.27	11.21
Left TLE (postsurgical)	2			
M		48.44	13.03	40.97
SD		15.47	9.86	1.37
Left TLE (Total)	11			
M		54.49	32.86	35.17
SD		10.10	20.07	14.04

Change Scores

Change scores were calculated for each patient in this study. A "verbal distractor change score" was computed by subtracting the delayed retention percentage after the verbal distraction from the delayed retention percentage after the no distractor condition and dividing that number by the delayed retention percentage score of the no distractor condition. A "nonverbal distractor change score" was calculated the same way, using delayed retention percentages following the nonverbal distractor condition. These change scores are displayed in Table 5.

Presurgical Patients. Change scores were entered into a 2 (right TLE, left TLE) x 2 (verbal distractor change score, nonverbal distractor change score) repeated measures ANOVA. No significant interaction between side and change score was obtained [F (1, 15) = .018, p = 896] and change score did not show a significant main effect (F (1, 15) = .628, p = .440].

Pre- and Postsurgical Patients. Because there were no differences between the presurgical patient groups for change scores, postsurgical patients were added to the analyses to increase power. Change scores for all TLE patients were entered into a 2 (side) x 2 (change score) repeated measures ANOVA. Even with the increased power, no significant interaction between side and change score was obtained [F (1, 24) = .623, p = .438] and there was not a significant main effect of change score (F (1, 24) = .027, p = .871].

Table 5.
Change Scores

Condition	Right TLE	Group Right TLE/ATL	Left TLE	Left TLE/ATL
No Distractor - Verbal Distractor				
M	.230	.320	.310	.377
SD	.110	.190	.386	.390
No Distractor - Nonverbal Distractor				
M	.272	.357	.368	.322
SD	.310	.298	.259	.266

Note. A score of zero represents no change. A score closer to one represents greater change, with better performance after the "No distractor" condition. A score closer to -1 signifies greater change with better performance during the distractor condition.

Perceptual Organization

Table 6. contains means and standard deviations regarding PO Scores.

Presurgical Patients. An ANOVA was conducted to determine whether patients with right hemisphere damage and left hemisphere damage differed in their organizational approach to the complex figure copy. The ANOVA was a repeated measures 2 (side) x 2 (condition) design, with PO score as the dependent variable, including data from all 20 presurgical epilepsy patients. The results determined that there was no significant interaction between side of seizure focus and PO Scores [F (1, 14) = .167, p = .689].

Pre- and Postsurgical Patients. Again, to increase the power of the analyses, postsurgical patients were added to the design. A second 2 x 2 repeated measures ANOVA was conducted to determine whether the entire group of patients with either right or left hemisphere damaged patients differed in their organizational approach to the complex figure copy. The results determined that there was still no significant interaction between side of seizure focus and PO Scores [F (1, 22) = .400, p = .534] even when all of the patients were included.

Table 6.

Perceptual Organization Scores - Patient Groups

Condition	Group			
	Right Pre	Right Focus	Left Pre	Left Focus
Verbal Distraction, Copy Trial				
M	83.98	83.17	76.26	78.76
SD	17.34	14.9	15.13	14.62
Nonverbal Distraction, Copy Trial				
M	84.78	84.94	82.84	84.96
SD	11.47	17.54	19.42	10.50

Correlational Analyses

Because the sample size was relatively small, and previous analyses showed very little difference in performance between the pre- and postsurgical patient groups, both pre- and postsurgical TLEs were included in the following analyses. Ten right TLE and nine left TLE patients performed a list learning test (HVLT-R or CVLT). Therefore, percent delayed retention on the list learning test was calculated for those patients to determine a "verbal percent retention score." For the right TLE group, Pearson's Product bivariate correlational analyses indicated positive, but insignificant correlations were found between verbal retention and percent delayed retention of the complex figure after no distraction ($r = .086$; $p = .814$), verbal distraction ($r = .275$; $p = .442$), and nonverbal distraction ($r = .208$; $p = .564$). See Figure 2 for a plot of these correlations. None of the correlations were significantly different form each other.

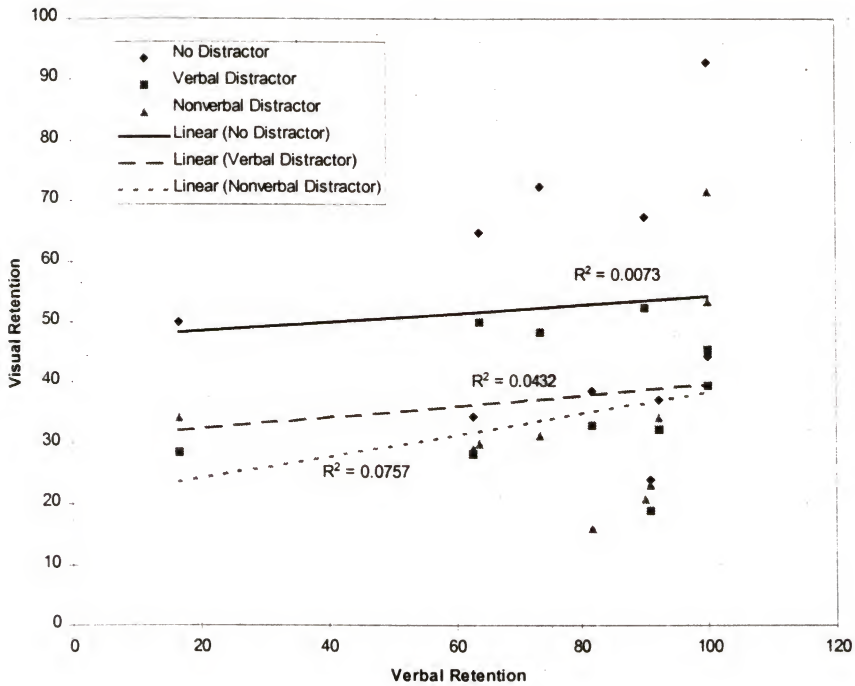

Figure 2. Correlations of the right TLE patients between verbal and visual retention under the three distractor conditions (n = 10).

Verbal retention scores of the left TLE group correlated positively but not significantly with percent retention of the figure after no distraction (r = .298, p = .436) and nonverbal distraction (r = .026, p = .948). However, there was a significant positive correlation between verbal retention scores and percent retention of the figure after verbal distraction (r = .718, p = .029). These correlations are shown in Figure 3. The only significant difference between correlations was obtained for the correlation between verbal retention and figure retention after verbal distraction and figure retention after nonverbal distraction (p = .032).

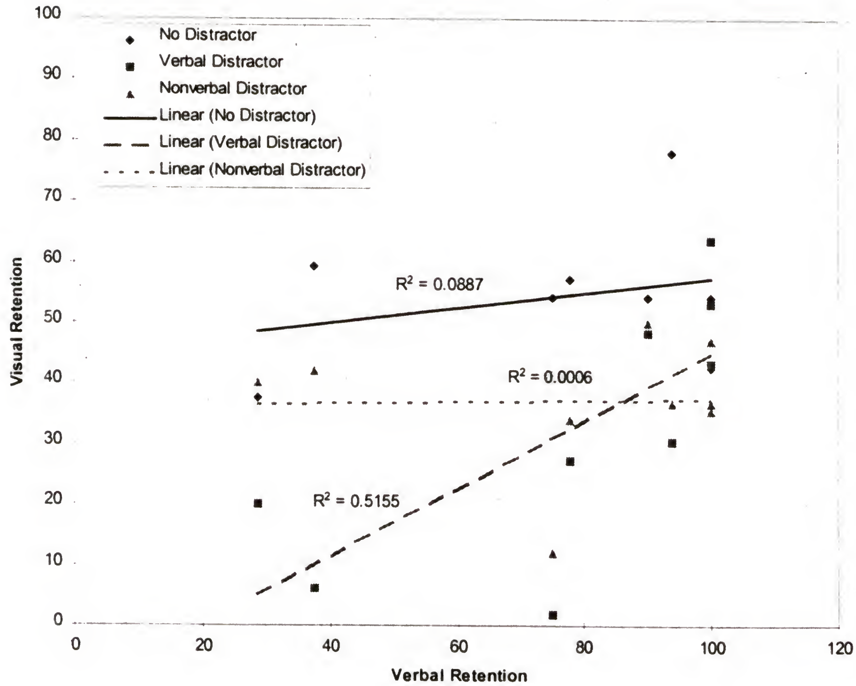

Figure 3. Correlations of the left TLE patients between verbal and visual retention under the three distractor conditions ($\underline{n} = 9$).

Within Group Differences

Post-hoc analyses were performed to determine if the right TLE group had significant within group variance that was contributing to nonsignificant between group effects. Based on the average retention of the pilot subjects, right TLEs were grouped as either "low" (less than 40%) or "high" (greater than or equal to 40%) retainers after verbal distraction. Based on this method, four patients were classified as "high" retainers and six as "low" retainers within the right TLE group. Within the left TLE group, there were four "high" retainers and five "low" retainers. It was hypothesized that "low" retainers would have greater verbal memory skills, and thus rely on those skills more, resulting in greater disruption of encoding during the verbal

distraction task. "High" retainers were hypothesized to have lower verbal memory abilities and therefore not as reliant on compensatory verbal encoding during the copy trial of the figure, resulting in less disruption of figure encoding during the verbal distraction condition.

T-tests compared high and low retainers within each patient group on the dependent variable verbal percent retention. Results indicated that, within the right TLE group, there were no significant differences between high retainers ($\underline{M}$ verbal percent retained = 81.73, $\underline{SD}$ = 16.35) and low retainers ($\underline{M}$ = 74.03, $\underline{SD}$ = 30.91) for verbal retention ($\underline{t}$ = -.452, $\underline{p}$ = .664). Within the left TLE group, there was a significant difference between the verbal percent retained scores of the high ($\underline{M}$ = 97.5, $\underline{SD}$ = 5.0) vs. the low ($\underline{M}$ = 62.53, $\underline{SD}$ = 28.04) retainers ($\underline{t}$ = -2.74, $\underline{p}$ = .048).

Memory for Features

An a posteriori hypothesis stated that memory for nameable features within the figures would be worse after verbal distraction than after nonverbal distraction. A one-way 2 (side) x 2 (condition) repeated measures ANOVA indicated that there was no interaction between side of seizure focus and number of features recalled after the two conditions [$\underline{F}$ (1,24) = .000, $\underline{p}$ = .993]. Therefore, a paired samples t-test was conducted to determine if, as a group, the TLE patients recalled more features after the nonverbal distractor than they recalled after the verbal distractor. The patients recalled an average of 2.6 ($\underline{SD}$ = 1.7) features after nonverbal distraction and 2.9 ($\underline{SD}$ = 1.8) features after verbal distraction. Those scores were not significantly different ($\underline{t}$ = .793, $\underline{p}$ = .435). These results did not support the a posteriori hypothesis, nor were they consistent with the results found in the normal pilot group.

Power Analysis

The effect sizes from prior published studies that found significant differences between patients with right and left temporal lobe epilepsy on visual memory measures similar to those analyzed in this study were, on average, about .5. With the reported sample size of 13 to 16 individuals per cell, power to detect an effect size of .5 was P = .53. This level is somewhat below an ideal level to minimize Type II errors rates.

CHAPTER 5

DISCUSSION

The present study was designed to determine the effects that concurrent verbal or nonverbal distraction tasks would have on memory for a complex figure. A group of normal pilot subjects made more errors during the nonverbal distractor task than during the verbal distractor task. However, retention of the complex figure was comparable after both the nonverbal and verbal distractors. Therefore, the difference in difficulty between the two tasks was thought to be negligible.

For the pilot group, memory performance was as hypothesized. A distractor present during the copy trial of the CFT resulted in decreased memory for the figure when compared to the no distractor condition. Memory for the figure was not differently affected whether the distractor was verbal or nonverbal in nature. However, results indicating that fewer nameable features were recalled after the verbal distractor provided some evidence that the verbal distractor task did, in fact, negatively impact verbal encoding.

There was a significant relationship between verbal retention scores and delayed retention of the figure presented without distraction. This relationship may mean one of two things. First, the relationship may indicate that there is a measurable verbal component to the visual memory test. Perhaps the pilot subjects relied on verbal encoding to remember some components of the complex figure. If this is true,

the nonsignificant correlations between verbal retention and retention of the figures after either verbal or nonverbal distraction could indicate that both the verbal and the nonverbal distractor were interfering with verbal encoding. A second possibility for the significant relationship between verbal retention and figure retention without distraction could result from the fact that normal individuals could flexibly use verbal or nonverbal encoding. It is likely that when the distractors were present the CFT was simply made more difficult, reducing the similarities between this test and an easier verbal memory test.

Hypotheses regarding perceptual organization during the copy phase of the figures stated that neither verbal nor nonverbal distraction would cause major impairment in organizational abilities. This was found to be true in the pilot sample. Seemingly, neither distractor task disrupted general visuospatial abilities.

Like the pilot subjects, the epilepsy patients made a significantly higher percentage of errors during the nonverbal task when compared to the verbal task. Pilot data showed that the slightly more difficult distractor did not affect memory performance any more than the easier distractor task in our pilot sample. Therefore, the difference in difficulty between the two distractor tasks was not considered a critical factor when performance of the patient groups was studied.

The hypothesis that the right TLE patients would have worse memory performance than the left TLE patient group after verbal distraction was not supported in this study, whether percent retention scores or memory change scores were analyzed. The lack of significant findings between conditions indicates that perhaps the right TLE patients are not relying on verbal encoding strategies more than the left

TLE patients. If verbal encoding is not responsible for documented lack of sensitivity of the ROCF to right medial temporal lobe damage, than other possible explanations must be considered.

There are several theories that could explain why right TLE patients are able to remember visuospatial information despite damage within the right temporal lobe. The first possibility is that perhaps visuospatial abilities are more widely distributed throughout the non-dominant hemisphere than previously thought. If so, traditional assessment techniques such as figure memory may not be specific enough to precisely measure right medial temporal lobe functioning. Evidence that nonverbal abilities are widely distributed has been obtained in recent imaging studies. Ungerleider (1995) explained, in a recent review of the neuroimaging literature, that research on monkeys has shown multiple cortical areas work together to process and store different aspects of visual stimuli. Many typical nonverbal memory tests include several of these different aspects such as object features, color, movement, and spatial orientation. Each of these features may be processed in a different way, recruiting the use of different cortical areas.

Researchers utilizing neuroimaging techniques have found that a simple visuospatial task, such as imagining a mental route, activates a wide range of cortical areas including superior occipital, posterior parietal, and posterior inferotemporal cortex, as well as several regions within the prefrontal cortex (Goldman-Rakic, 1988). Therefore, lesions in different cortical areas could, in theory, cause impaired performance on the same test for different reasons. Conversely, inconsistent patterns

of impairments across tests could be a factor of slight variances in the specific processes required for each.

Another study examined the associations between episodic memory and MRI volumetric measurements of various neural structures (Martin et al., 1999). Results indicated that, while verbal memory performance was significantly correlated with only left hippocampal and mammillary body volumes, visual memory was related to both right and left amygdala and right mammillary volumes. Performance on visual memory tests was not, however, related to right hippocampal volumes. According to these results, it appears that visual memory is mediated by both bilateral and extrahippocampal structures.

After a review of hundreds of brain imaging studies, Cabeza and Nyberg (2000) reported more evidence that perhaps memory for nonverbal information is more widely distributed throughout the cortex than memory for visual information. A majority of the reviewed studies that investigated memory found that encoding of verbal information led to activation in left frontal and left medial temporal regions. Studies that investigated encoding of nonverbal information (objects, faces) reported activation in bilateral frontal areas, the right cingulate region, bilateral temporal areas (including the medial temporal lobe and area 37), and bilateral occipital regions. Clearly, studies investigating the encoding of nonverbal material generally found more widespread activation.

The second possibility for the lack of sensitivity of traditional nonverbal tests is that the right hippocampus might be more involved with coding spatial, rather than object based, information. Notable, most tradition nonverbal memory tests are based

on visual objects rather than spatial relationships. The animal literature provides evidence that the hippocampus is specifically involved in memory for spatial locations. Becker, Walker, and Olton (1980) ran a group of hippocampectomized rats and a group of rats with extrahippocampal brain lesions through an eight-arm radial arm maze. A radial arm maze typically consists of a center platform with a number of straight passageways (arms) extending off in different directions. Healthy rats can easily be trained to venture down each arm exactly once to retrieve a food pellet at the end. However, in Becker et al.'s study, rats with bilateral fimbria-fornix lesions (a system directly related to hippocampal functioning) were not able to perform the test correctly. Specifically, the rats with hippocampal damage had the same chance of entering an empty arm, which they had already visited, as a new arm. Rats with lesions in other brain regions that did not effect hippocampal functioning (e.g., caudate, frontal cortex) did not demonstrate this deficit. The researchers concluded that the fimbria-fornix lesioned rats were unable to remember the spatial locations of the arms they had already visited (Becker et al., 1980).

In another study, monkeys with bilateral hippocampal lesions were found to be notably impaired on a spatial reversal task in which reward was given for selection of alternating spatial locations, after bilateral hippocampal lesions. These same lesions, however, did not impair performance on an object reversal task, where selection was based on 3-dimensional objects as opposed to locations (Mahut, 1971).

Evidence also exists in the literature that the right hippocampus in humans may be more involved with processing and encoding purely spatial information as opposed to involvement in object based "nonverbal" information. In contrast to a

lack of success enjoyed by traditional nonverbal memory tests in discriminating right vs. left TLEs, several experimental tasks that assess *spatial skills*, and in particular spatial memory, have recently been successful in performing this distinction.

Using a test that assesses spatial memory for object locations ("Nine-box Maze"), researchers found that patients with right temporal epilepsy tested before or after resective surgery were impaired on the test (Abrahams et al., 1997; Abrahams et al., 1999). The Nine-box Maze consists of nine cylindrical containers set out in a circular array on a table. The subject watches as an experimenter hides objects in three of the boxes. The subject then moves to a different position around the table and must remember the names of objects that were hidden as well as locations in the boxes. Researchers found that, while the right TLE and ATL patients were not significantly different from left patient groups or a control group on memory for the objects, they were impaired on memory for the locations of the objects.

Another group of researchers also found specific spatial deficits in right lesioned patients. Feigenbaum, Polkey, and Morris (1996) designed the Executive Golf Test as a human analogue the radial arm maze. During this test, subjects watch a simulated golf game on a computer screen. For each trial they must guess, from an array of "holes", which hole the ball will be putted into. They are given the instructions that each hole will receive exactly one ball. Therefore, the subjects must keep track, as the trials continue, of which holes had been filled and which had not. Additionally, since they must continue guessing until they have picked the correct hole, the subject must keep track of which holes they have or have not yet picked during each trial. When the researchers compared the performance of right and left

ATL patients with that of a control group, they found that the right patients were significantly worse on this test than controls. The right patients' impairment was especially salient during more difficult trials, when there were more holes, and thus more spatial locations to remember as the test continued. The researchers suggested that their findings implicate the right temporal structures in spatial memory.

Nunn, Graydon, Polkey, and Morris (1999) used structural MRI to quantify the extent of temporal lobe resection in postsurgical TLE patients. They found significant correlations between the amount of the right hippocampus removed and performance on a test requiring the retention of the spatial locations of 16 objects. They also found that, when right temporal lobectomy (TL) patients were matched to normal controls on object recall scores, the right TL patients were still significantly worse at remembering spatial locations. The authors argued that spatial memory impairment was associated with right temporal lobe resections and requires the functioning of the right hippocampus specifically.

Based on consensus within the current literature, some researchers believe that the type of spatial processing a test requires is the most important factor when assessing right temporal lobe functioning. Two types of spatial processing have been described in the literature. The first is allocentric, which is viewer independent. The second is egocentric, or viewer dependent. O'Keefe and Nadel (1978) first described these distinctions, which were first discovered during animal research. For example, single cell recordings in the hippocampi of rats indicated active "place cell" that responded to specific locations during maze tasks.

More recently, Rolls (1999) reviewed several cell recording studies in which non-human primate hippocampal neurons responded to allocentric spatial representations. Conversely, the parietal cortex contained neurons that responded to egocentric representations. It is feasible that, from an evolutionary perspective, when the left hemisphere became allocated to different aspects of language in humans, the right hemisphere remained for spatial processing. A complex figure test, like many other traditional visual memory tests, is completely egocentric. That is, as the examinee copies or recalls the figure, he or she is always in the same position with regard to the different components of the figure. Allocentric tests that have been shown to discriminate between patients with right versus left TLE include the Nine-box Maze (Abrahams et al., 1997), described above, and the Rotating Golf Test (Feigenbaum et al., 1996), similar to the Executive Golf Test described above except the spatial array rotates as the test progresses.

Although there were no significant visual retention differences between right and left epilepsy patient groups, the current study also aimed to determine whether different organizational strategies would affect the copy trials of the patient groups. Gainotti and Tiacci (1970) reported that patients with right hemisphere damage made more spatial errors and demonstrated a fragmented approach to copying designs, while those with left hemisphere damage tended to make simplified reproductions and recalled less features. More recently, Lange et al. found that patients with right hemisphere damage have poorer copy organization than those with left hemisphere damage or non-brain injured controls (Lange et al., 2000). Therefore, the hypothesis for this study was that patients with right TLE would demonstrate a less organized,

more fragmented copy strategy. However, perceptual organization (PO) scores between the right and left patient groups did not differ under either distractor condition. In addition, the PO scores of both patient groups were highly consistent with the PO scores achieved by the pilot sample. It is possible that the chosen method for scoring the copied figures on organizational quality was simply not the most sensitive method. Perhaps the method utilized in this study was more quantitative in nature than techniques used in past research. Another possibility is that patients with right vs. left TLE actually do not have that different of copying strategies. Two studies investigating the effects of left and right brain injury on copy style (Binder, 1982; Trojano, De Cicco, and Grossi, 1993) found that patients with right and left hemisphere damage both demonstrated more fragmented organizational styles when copying a visual design when compared to normal controls. Another study that examined visuoconstruction skills in patients with right or left hemisphere damage showed that both group had deficits. The patients with right hemisphere damage were more likely to distort the overall form of designs while the patients with left hemisphere damage tended to distort the local, or featural aspects of the designs (Delis, Kiefner, and Fridlund, 1988). The current paper did not investigate featural verses global spatial distortions.

Correlational analyses between verbal retention and figure memory within the patient groups showed that, for the right TLE patients, visual memory performance was not related to verbal memory performance under any of the test conditions. The lack of significant correlations perhaps indicates that the right patients were not utilizing verbal encoding techniques during any of the copy conditions. Within the

left TLE group, the only significant relationship was found between verbal memory and visual memory under the verbal distractor condition. This finding is directly opposed to the hypothesis that the verbal distraction technique prevents the use of verbal encoding strategies, and suggests that, in the left TLE group, verbal encoding could have been more heavily utilized during the verbal distraction. However, the fact that left TLE group with better verbal memory had less overall temporal tissue damage and therefore could have better support for remembering both verbal and visual material.

The a posteriori hypothesis that right TLE subjects with better figure retention after verbal distraction would have lower verbal retention scores was not supported. It was shown that the right TLE subjects with average figure retention after verbal distraction had comparable delayed verbal memory performance to those with below average figure retention after verbal distraction. Interestingly, within the left TLE group, there was a significant difference in the verbal retention scores of those who remembered an average or above average amount of visual information after verbal distraction and those who did not. Those with better figure retention after verbal distraction actually had significantly better verbal retention scores.

There were some limitations in this study that should be noted, and perhaps explored in future research. First, there is a possibility that the nonverbal distractor task actually did have a verbal component, and may have caused some disruption in verbal encoding during the copy trial of the complex figure test. However, if that were the case both distractor tasks should have caused a decline in memory performance within the right TLE group. Because that was not true, it can

confidently be stated that the use of verbal encoding is not allowing patients with right TLE to compensate for impaired visuospatial memory on a complex figure test.

A second concern with this study is that perhaps the verbal distraction task was not sufficient to tie up verbal encoding completely. Although the fact that the verbal distraction task decreased memory for nameable features in the normal pilot sample provided some evidence that the task did indeed affect verbal encoding, this finding was not replicated in the patient group. However, past research shows that irrelevant speech is adequate to impede in verbal processing, at least to some degree (Baddeley, 1992). Therefore, it would have been expected that verbal encoding would be at least somewhat hindered during the verbal distraction. If that was true, the right TLE group would be expected to show some decrease in performance compared to the nonverbal distractor condition or the left TLE group's performance. Because the average memory performance of the right TLE group was indistinguishable from the performance of the patients with left TLE, it is likely that the reason for the right group performing as well as they do on figure memory tests is not due to compensatory verbal encoding. However, utilizing a technique that impairs verbal encoding to an even greater degree, such as articulatory suppression, might be a more definitive way of in determining definitively that right TLE patients are not relying on verbal encoding during the CFT. This study did not utilize an articulatory suppression technique because it was difficult to design a nonverbal task parallel to articulatory suppression. The effects of articulatory suppression on nonverbal memory should be investigated in future research.

Another weakness of the current study is that the main hypotheses were based on Baddeley's theories about fractionated working memory (Baddeley, 1992). Although Baddeley and other researchers have published numerous studies in support of his theory (e.g., Salame and Baddeley, 1987) it is still a theory. If the theory were an oversimplification of the true memory processes (e.g., there exists more than one phonological loop) the basic assumptions on which this study were based could be erroneous, possibly resulting in findings that do not fit the original hypotheses.

The small sample size could have been a limitation of this study. Based on the average effect size found in previously published studies, the chances of correctly rejecting the null hypothesis regarding visual retention with the current sample size was somewhat below the level considered ideal. While the modifications to the complex figure task were designed to increase group differences and thus create more statistical power than observed in previous studies, there is a chance that effects were not found due to low power.

The possibility exists that the criteria under which the patient groups were selected was another limitation. While they were carefully evaluated to make sure the epileptic focus involved a temporal lobe, they were not all found to have evidence of hippocampal sclerosis. There remains the possibility that patients with hippocampal sclerosis perform differently on memory tests than those without sclerosis. Because the patient groups in this study contained some patients with hippocampal sclerosis and some without, it is possible that including subjects without sclerosis obscured any potential findings. Other patient variables that were not analyzed in this study, such as age of seizure onset and estimated lifetime seizures, could also have been a source

of within group variance. Future research should include such variables in order to determine the effects they have on memory performance.

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BIOGRAPHICAL SKETCH

Because my father is a clinical psychologist and psychology professor, I was introduced to psychology at a young age. There was no question that it would be my major when I was an undergraduate at the University of Minnesota. Throughout my undergraduate education I became acquainted with and fell in love with the specialty of neuropsychology. I received my graduate education at the University of Florida, and completed an internship with a neuropsychology specialty at Long Island Jewish Hospital in New York. I am excited to have the opportunity to complete my training, at the postdoctoral level, back in my home state at the Medical College of Wisconsin.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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